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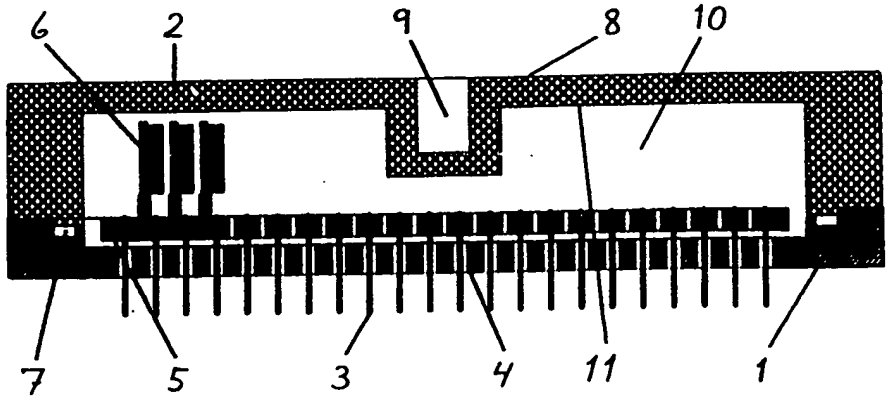

(57) Abstract

A module containing electronic components (6) for use in fast computers, where much is dissipated from the components (6) therein,is self-supplied with its own primary cooling system. The module is constituted by a "hermetically" closed container filled with an inert liquid with a low boiling point. The module consists substantially of a bottom part (1) and a top part (2). The heat from the electronic components (6) is transferred from the components to the internal top surface (11) of the module via the phase transition of the liquid (i.e. boiling), its natural convection and the new phase transition (i.e. condensation at the inner surface (11)). The module is fastened with an external surface (8) in direct thermal contact with a corresponding surface of a secondary cooling system. The module is constructed to withstand the internal pressure which arises in the cavity (10).

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A METHOD AND A MEANS FOR COOLING ELECTRONIC COMPONENTS

The present invention relates to a method for cooling electronic components mounted inside a module of box-like construction, and also relates to a module adapted for the same purpose.

In fast and powerful computers, rather large amounts of heat are normally generated in the electronic components, and for this reason different types of cooling systems have been developed.

Usual techniques comprise air cooling by means of mechanical fans, metal cooling fins with a large surface area, liquid cooling by means of piping, or equally well combinations of such techniques.

It has also been made attempts at modifying the air cooling technique by replacing the air with a liquid which surrounds the electronic components completely. This liquid must be inert, i.e. it must not attack the components chemically in any manner whatsoever, and the electrical characteristics of the liquid must also be favourable.

In particular, attempts have been made using liquids with a low boiling point, i.e. so that the heat energy from the electronic components is spent in boiling the liquid in order thereby to maintain a stable temperature. The energy is transported further by convection and subsequent condensation somewhere else in the system. Usually in this art, a special condensation element has been used inside the chamber where said components and said liquid are situated, and this condensation element is coupled to the outer world with liquid-conducting pipes, see e.g. "Boiling heat transfer in electronics" by D. L. Cochran, NEPCON Conference, June 1968. In such a context it has also been usual to equip the chamber with a flexible wall or an expandable bellows to avoid a too high pressure.

The principles behind a cooling method of the type to be mentioned here, is illuminated in the article "Better high-power-density circuit cooling through nucleate boiling" by John H. Powers, Electronic Packaging and Production, May 1970.

The goal of the present invention is to provide a cooling method and an electronics containing module for primary cooling of the components contained, thereby in an effective manner stabilizing the operating temperature of the electronic components within minimum volume and without need of other connections than the electrical connections. Furthermore, fast and simple replaceability of the complete module results, and good opportunities for internal service in a module are also obtained.

These goals are reached by putting into use a method and a module of the type which is defined precisely in the enclosed patent claims.

The invention shall be illuminated more closely with reference to a non-limiting embodiment example, and with reference to the enclosed drawings, where

fig. 1 shows an exemplary embodiment of a module in accordance with the present invention in the form of a section through the module, and

fig. 2 shows a diagram of measurements of connected values of dissipated power and temperature in the module.

Fig. 1 shows a cross-section through an exemplary embodiment of a module in accordance with the present invention. The module consists mainly of a bottom part 1, which suitably may be manufactured from "Kovar" material (an alloy with thermal expansion adapted to that of glass), as well as a top part 2 which preferably is made of aluminum. The bottom part 1 and the top part 2 are preferably fastened together along the edges, together forming a box with an internal cavity 10. The two parts are held together by means of fastening devices (not shown), e.g. threaded bolts, and to ensure an adequate seal between the two parts 1 and 2, a groove 7 has been cut to accomodate a seal packing in one of the peripheral surfaces where the two parts 1 and 2 engage each other.

In the disclosed embodiment the bottom part 1 is equipped with a plurality of holes through the bottom. These holes serve as passages for several contact pins 3 for providing electrical connections with the surroundings. On the inside, these contact pins 3 are preferably terminated in a printed

circuit board 5 arranged on the bottom of the cavity 10. The electronic components are situated on the circuit board 5, e.g. as substrates 6 for integrated circuit chips. These substrates 6 are preferably mounted on edge, extending upward from the circuit board 5.

The holes in the bottom plate 1 are sealed around the contact pins 3 with a glass material 4. These glass seals 4 provide both a pressure seal, electrical insulation around the contact pins 3 and the necessary electrical impedance matching by precise adaptation of pin diameter, hole diameter and glass permittivity. As an example, the hole diameter may be 3 mm, and the contact pins 3 may have a diameter of 0,4 mm, arranged in a grid with 4 x 4 mm distance.

In order to complete the module, the following operation is executed: Through sealable openings (not shown) a vacuum is established in the cavity 10. It is important that no remaining gas is present in the cavity, so as to avoid contamination of the liquid to be filled into the cavity 10. The liquid which is poured into the cavity, is necessarily chemically neutral, and it is important that it has a low boiling point. At least, the boiling point must be lower than 60°C at normal pressure. As an example of an appropriate liquid, a fluorocarbon liquid from 3M Company, trade name FC87, can be mentioned. This liquid has a boiling point of 31°C.

The cavity 10 is filled almost completely with the liquid, and then the openings are sealed.

When the module is put into electrical operation, heat is generated from the electrical components 6. The low-boiling liquid then starts boiling quite adjacent to the components, and in this connection a powerful convection flow is established. In the exemplary embodiment of the module, the top part 2 serves as a cold side, because the exterior side 8 of the top part 2 has a good thermal, i.e. mechanical contact with a secondary cooling system, e.g. a system based on liquid flow in pipes. What happens next, is that the vapour which has been created by the boiling around the components 6, is condensed against the cooler interior side 11 of the top part 2, and falls back as a liquid. Thus, there is achieved a dynamic

equilibrium state with a stabilized temperature for the electronic components 6. The special aspect of this situation is that no attempt is made to lower the pressure which necessarily arises, but instead the module is constructed to withstand this pressure. The module operates rather like a "pressure cooker".

In order to provide good contact with the secondary cooling system, the external surface 8 of the top part 2 is quite smoothly polished, and the surface has a slightly concave design, so that a good engagement is achieved when tightening a (not shown) center bolt which is mounted in a mounting hole 9 in the center of the top part 2.

The secondary cooling system, which may be a liquid cooled plate, a plate with gas cooled fins or similar, is equipped with a correspondingly polished surface, to which the module is fastened. A possible piping arrangement in the secondary cooling system is simplified in that the module can be fastened by means of only one bolt.

It is advantageous if the internal condensation surface 11 in the module is slightly roughened or uneven in order to promote condensation and achieve a large condensation surface area.

It is also an advantage if the liquid to be used, is degassed in vacuum before it is poured into the module, because possible other gases which might exist in the module cavity 10, will reduce the cooling ability drastically by forming an insulating layer between the vapour and the condensation surface 11.

The integrated circuit chips are preferably arranged on an array of ceramic substrates 6, which substrates are surface mounted on the printed circuit board 5 in the module bottom. The printed circuit board 5 is then used both for interconnecting the ceramic substrates and for electrical connections to the surrounding milieu. The conductor pins 3 from the circuit board 5 are run through coaxially-shaped glass sealed passages which provide a possibility of impedance matching as mentioned above.

The main advantages with the module in accordance with the invention can in short be summarized as follows:

The module is independent, and can be handled in the same manner as any other component, i.e. no pipes or flexible tubes must be connected with the module. This means that is is not necessary to shut the secondary cooling system down when a module must be replaced.

The electronic components inside the module are completely surrounded by a liquid, which provides the possibility of cooling components of any shape.

With a corrrectly designed bottom plate, no leakage will occur regarding electromagnetic radiation in the radio frequency range.

Conducted measurements show that the "pressure cooker" system works satisfactorily. Fig. 2 shows measurement results produced from a module of typically hand-manageable size, about 115 x 115 x 26 mm^3 outer dimensions, and a somewhat smaller cavity (about 95 x 95 x 18 mm^3). The power dissipated from the set of components inside the cavity, in this case 32 integrated circuit chips, each one dissipating the same power, is plotted versus the stable temperature obtained in each chip (average for all chips), when the secondary cooling system temperature is 17,5°C.

It appears e.g. from these measurements that for a module with the stated dimensions, 10 watts per chip can be dissipated continuously at a chip temperature as low as about 52°C. In other words, the working life of the electronic components can be influenced in a favourable manner by means of a primary cooling system of the kind in accordance with the present invention.

CLAIMS

1. A method for primary cooling of electronic components or circuit boards (6) arranged in an internal cavity (10) in a closed module which is adapted for further conduction removal of heat by means of an external, secondary cooling system, which module is also equipped with a number of sealed and insulated lead-through arrangements of electrical conductors (3) to/from said components or circuit boards (6) for establishing external connections, where said cavity (10) is filled with a liquid and closed, so that the heat generated in the electronic components/circuit boards (6) is transported to at least one of the module walls (11) by the phase transition of liquid into vapour, the liquid/vapour natural convection flow as well as the condensation of the vapour on said at least one wall (11),
c h a r a c t e r i z e d in that when closing said cavity (10), the cavity (10) is sealed in a gas and pressure tight manner for primary cooling at a superatmospheric pressure, and the pressure inside said cavity (10) during operation is allowed to rise, due to said phase transition to vapour in dependence on the actual or desired power dissipation from the electronic components or circuit boards (6), the enhanced pressure providing improved conduction removal of heat from said components.

2. A method as claimed in claim 1,
c h a r a c t e r i z e d in that prior to filling liquid into the cavity (10), a vacuum state is established in said cavity (10) so that no extraneous gas shall occur in the cavity (10) in addition to the possible vapour phase of the liquid.

3. A module containing electronic circuits or circuits boards (6), said module comprising a bottom part (1) and a top part (2) peripherally fastened together and between them defining a cavity (10) for accomodating said circuits or circuit boards (6), a number of sealed and insulated lead-through arrangements

with electrical conductors (3) to/from said circuits/circuit boards (6) being provided in at least one of said two parts (1, 2) for external contact formation, and at least one external module side (8) being adapted to provide good thermal contact with an external, secondary cooling system, and the module cavity (10) being filled with a liquid around said circuits or circuit boards (6),
c h a r a c t e r i z e d in that said module is completely sealed against gas or liquid leakage, also when the internal pressure is enhanced, and is arranged with a substantially constant inner volume, so that superatmospheric pressure is established during operation when the liquid boils due to the power dissipation from the electronic circuits or circuit boards.

4. A module as claimed in claim 3,
c h a r a c t e r i z e d in that said liquid is chemically inert.

5. A module as claimed in claim 3 or 4,
c h a r a c t e r i z e d in that said liquid is a fluorocarbon liquid with a low boiling point, i.e. lower than 60°C at normal pressure.

6. A module as claimed in any one of claims 3-5,
c h a r a c t e r i z e d in that said liquid is degassed in advance and that said cavity is pre-cleaned and evacuated, so that no other gas than possibly vapourized liquid can occur in the cavity (10).

7. A module as claimed in any one of claims 3-6,
c h a r a c t e r i z e d in that the seal between the two module parts (1, 2) is realized with screw bolts and a seal packing in a cut groove (7) in at least one of said parts (1, 2), so as to provide a possibility of access for service/ replacement of electronic components or circuit boards (6).

8. A module as claimed in any one of claims 3-7, c h a r a c t e r i z e d in that a printed bottom circuit board (5) is arranged along a bottom surface in said cavity (10), with direct contact connection to said electrical conductors (3), said bottom circuit board (5) constituting a basis for mounting integrated circuit chips or substrates (6) with integrated circuit chips mounted thereon.

9. A module as claimed in any one of claims 3-8, c h a r a c t e r i z e d in that said number of electrical conductors (3) passes out through a corresponding number of openings in a flat main wall in e.g. the module bottom part (1), said main wall then constituting the module bottom, pressure sealing, electrical insulation and simultaneously electrical impedance matching being effected by means of a glass material (4) filling said openings around each electrical conductor (3).

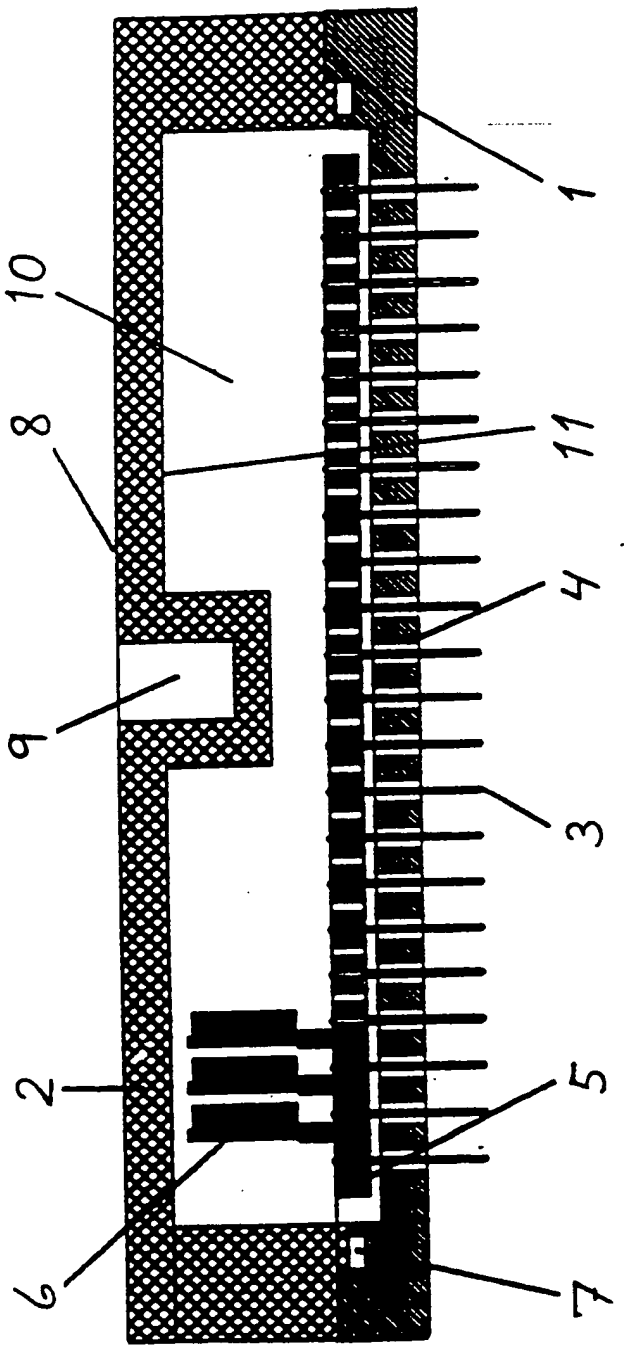

Fig. 1

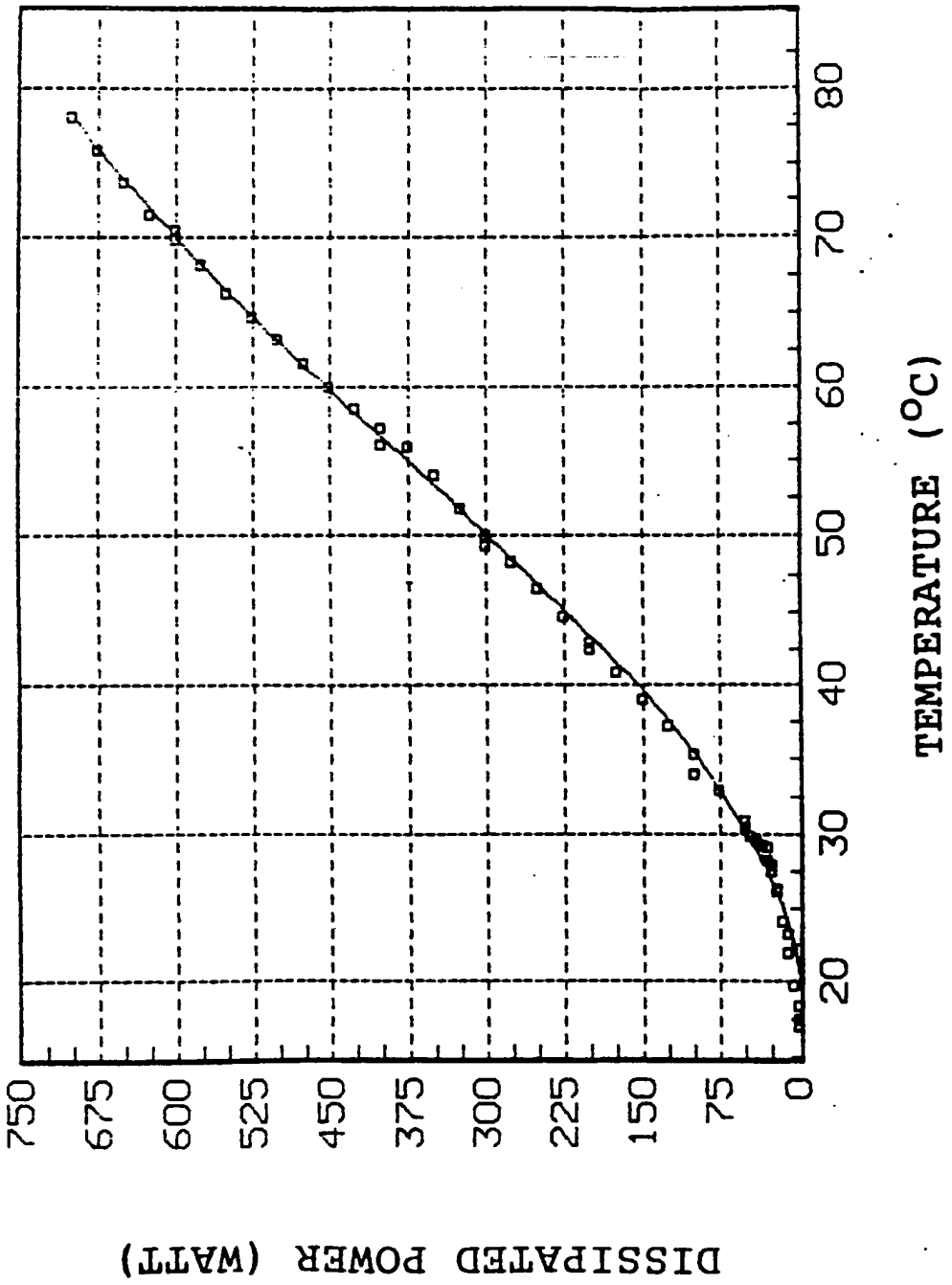
750
675
600
525
450
375
300
225
150
75
0
DISSIPATED POWER (WATT)
20
30
40
50
60
70
80
TEMPERATURE (°C)

Fig. 2

INTERNATIONAL SEARCH REPORT

International Application No PCT/NO 90/00160

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC5: G 12 B 15/02, H 01 L 23/42, H 05 K 7/20

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
IPC5	G 12 B, H 01 L, H 05 K

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched[8]

SE,DK,FI,NO classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category *	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
X	US, A, 4203129 (OKTAY ET AL) 13 May 1980, see figure 5 --	1,3
X	EP, A1, 0001123 (INTERNATIONAL BUSINESS MACHINES CORPORATION) 21 March 1979, see figure 1 --	1,3
X	EP, A2, 0144071 (FUJITSU LIMITED) 12 June 1985, see claims 1-18 --	1,3
X	EP, A1, 0268081 (BBC BROWN BOVERI AG) 25 May 1988, see claims 1-10 --	1-3

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* Special categories of cited documents: [10]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
1st February 1991	1991 -02- 12
International Searching Authority: SWEDISH PATENT OFFICE	Signature of Authorized Officer: SVEN-OLOF WIRLEE

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ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.PCT/NO 90/00160

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the Swedish Patent Office EDP file on 90-12-28
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Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US-A- 4203129	80-05-13	CA-A-	1115822	82-01-05
		EP-A-B-	0007015	80-01-23
		JP-C-	1409160	87-11-24
		JP-A-	55012798	80-01-29
		JP-B-	62011509	87-03-12
EP-A1- 0001123	79-03-21	CA-A-	1097788	81-03-17
		JP-C-	1085797	82-02-26
		JP-A-	54044479	79-04-07
		JP-B-	56031743	81-07-23
		US-A-	4138692	79-02-06
EP-A2- 0144071	85-06-12	CA-A-	1230184	87-12-08
		JP-A-	60148155	85-08-05
		US-A-	4796155	89-01-03
		JP-A-	60148156	85-08-05
		JP-A-	60116155	85-06-22
		JP-B-	1004343	89-01-25
		JP-C-	1526390	89-10-30
		JP-A-	60117646	85-06-25
		JP-B-	1000815	89-01-09
		JP-C-	1521567	89-10-12
		JP-A-	60117647	85-06-25
		JP-C-	1526392	89-10-30
		JP-A-	60133743	85-07-16
		JP-C-	1526393	89-10-30
		JP-A-	60138946	85-07-23
		JP-C-	1526395	89-10-30
		JP-A-	60142550	85-07-27
EP-A1- 0268081	88-05-25	JP-A-	63116452	88-05-20
		ZA-A-	8708041	88-04-29